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BIOTECHNOLOGY TEACHING

The relationship among knowledge of, attitudes toward and acceptance of genetically modified organisms (GMOs) among Slovenian teachers

Andrej Šorgo
Faculty of Natural Sciences and Mathematics
University of Maribor
Maribor, Slovenia

Jana Ambrožič-Dolinšek*
Faculty of Education and
Faculty of Natural Sciences and Mathematics
Koroška 160, 2000
Maribor, Slovenia
E-mail: jana.ambrozic@uni-mb.si

Website: http://www.uni-mb.si/

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Abbreviations: GM: genetic modifications
GMO: genetically modified organisms

The objective of this study was to investigate knowledge about, opinions on and attitudes toward and finally readiness to accept genetically modified organisms (GMO) among Slovenian teachers. On average, they have higher levels of knowledge in classical genetics, and poor levels of knowledge about modern issues in biotechnology, and their attitudes toward GMOs are not extreme. They make decisions based on the acceptability of a particular GMO and not on GMOs in general, following two patterns: genetic modifications (GM) microorganisms and plants are more acceptable than animals, and GMOs are more acceptable if they can not be used directly for consumption and produce something recognized as useful. The relationship among knowledge of, attitudes towards and readiness to accept GMO showed that there is no correlation between knowledge and attitudes, only a weak correlation between knowledge and acceptance, and a solid correlation between attitudes and readiness to accept GMO. The practical implication of our findings is that acceptance of GMOs will not be changed by providing new technical or scientific information to teachers but by changing attitudes. The appropriate strategies and actions for improving university courses in biotechnology and the implication for classroom science activities and future research are discussed.

Genetically modified organisms (GMOs) genetic modifications and accompanying research and technologies have become some of the most controversial issues in our society. We are witnesses to intense debate among proponents and opponents of genetic modification in almost all fields where such technologies have emerged or are even foreseen, with particular attention focused on agricultural applications and genetic modifications (GM) food (Pardo et al. 2002; Christoph et al. 2008). Such debate takes place not only within the Science community but also in the Social Sciences and Humanities, in Politics, and among the general public as well (Flores and Tobin, 2002; Rodríguez Yunta et al. 2005; Stewart and McLean, 2005) To address both aspects -social and scientific- of such controversial issues (Fitzsimons, 2007), the term “socioscientific issues” was coined (Sadler, 2004; Sadler and Zeidler, 2005a; Sadler and Zeidler, 2005b).

Many concerns of the public (consumers) can be attributed to a lack of understanding of the scientific and science principles, and the processes and applications of biotechnology (Alberts and Labov, 2003). It has been recognized that additional knowledge can influence the ability to identify key issues and enhance understanding (Lewis and Leach, 2006). Better knowledge of biotechnology results in more positive attitudes (Prokop et al. 2007), while lack of knowledge and reflection create anxiety (Rodríguez Yunta et al. 2005). In practice, high media coverage and attention from environmental groups, in combination with very limited knowledge on the part of the public and abundant criticism, have failed to generate any significant contribution to the debate (pro, against) (Pardo et al. 2002).

The practical implications for the Biotechnology community are as follows: a) that public acceptance will play a major role in determining whether biotechnology

*Corresponding author

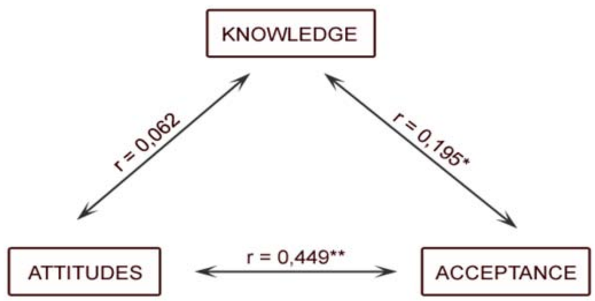

Figure 1. Correlation among knowledge about, attitudes towards and acceptance of GMOs among Slovenian teachers.* Denotes $P < 0.05$, ** denotes $P < 0.01$.

development continues to expand (Cavanagh et al. 2005); b) that the transfer of new findings from laboratories into the open field, food production, industry, medicine, etc. depend not only on scientific knowledge among scholars and the limitations of technological solutions, but also on legal, social, moral, ethical, and religious issues, as well (Lazarowitz and Bloch, 2005).

If we, as educators, start with an assumption that everyday (actual or potential) end users and consumers of biotechnological products usually do not possess appropriate knowledge about biotechnology issues and biotechnology thus simply "happens" to them, then one key questions is the following: what should be the content of such education, and where and how should actual and potential consumers be educated?

In the information jungle, where both trustworthy and corrupt sources are instantly available, we believe that schools should take their share of responsibility for educating young people about biotechnology. The rationale is that schools are formal institutions where knowledge is most often transferred from a science field, according to the scientific facts and principles, and this school knowledge comes mostly from valid sources, something that cannot be said for the knowledge gained in later life. So it should be the responsibility of the schools to inform students about scientific and technical aspects of biotechnology, with the benefits and disadvantages related to biotechnology, and thus to enable them to cope with such technology and form their own attitudes toward biotechnology. Because of the complexity of such issues, they should be taught in an interdisciplinary way and not restricted to the purely scientific aspects (Harms, 2002). Ideally, a school should give students a solid foundation, scientific reasoning, and knowledge of where and how to test resources. Worldwide, several attempts have been made to introduce knowledge about biotechnology in to schools, and the factors and values that can affect such teaching have been explored (Flores and Tobin, 2002; Serralheiro and Freire, 2002). General and technical upper secondary education in Slovenia, including Biology education, is highly affected by external state examination as a prerequisite to enter tertiary education (Ivanus-Grmek and Krecic-Javornik, 2004). Several attempts have been made to balance the high impact of examination results on the future career of a student with knowledge and attitudes towards issues not part of the examinations, but recognized as important in other aspect of life (Torkar and Bajd, 2006; Strgar, 2007; Šorgo et. al. 2008).

The key position in education goes to the teachers, and we can recognize them as a link between Science and society, since they transfer to students not only knowledge but personal views and opinions as well. In Slovenia only teachers of biology and related science subjects attended courses in genetics or biotechnology in their pre-service training, so the others rely on other sources. Even for biology teachers, knowledge in the field of biotechnology is outdated only a year or two after their University courses finish. Within the school world the biology teacher may be recognized as an “authority” on his/her educational field; however, in the case of socio-scientific issues, the teacher is frequently not qualified (trained) to cope with the social, ethical and moral aspect of such issues. In contrast, teachers of other subjects may cope better with the social issues but have flawed knowledge about the scientific aspects of biotechnology. For the students, this can only mean that they probably receive completely different opinions based on the same facts about the very same thing from different teachers at the same school.

The objective of our study was to investigate knowledge of genetics and biotechnology, opinions on and attitudes toward and acceptance levels of GM organisms among Slovenian primary, lower secondary and high school teachers. In our study attitudes are recognized as an individual's negative and positive thoughts about GMOs, and acceptance as willingness to use them in daily life. To our knowledge, this is the first such study on the teacher population in Slovenia, and we were not able to find related reports from other parts of the world. Our study parallels a number of related studies performed on different groups of actual or potential consumers or users of GM organisms and related technologies (Chen and Raffan, 1999; Lewis and Leach, 2006; Prokop et al. 2007) where different aspects were analyzed. There is a demand for such research not only among consumers but among other groups as well. The main reason is to assess the factors that can influence acceptance of genetic modifications and to design the appropriate strategies and actions to manage public expectations (Ronteltap et al. 2007). As biology teacher educators in pre-service courses and in-service training, we were not able to transfer findings from other studies to our population of teachers. The findings of the study are designed to represent a baseline for improvement in our university courses for pre-service biology teachers and forthcoming in-service training in biotechnology, in such a manner as not to bore teachers with things they already know nor spend time trying to dispel fears they do not have.

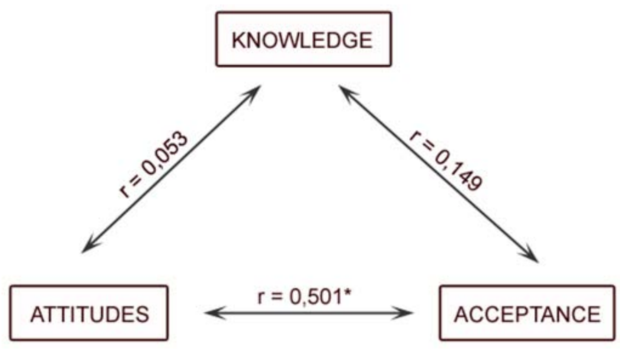

Figure 2. Correlation among knowledge about, attitudes towards and acceptance of GMOs among Slovenian teachers with a higher level of knowledge concerning genetics and biotechnology.* Denotes $P < 0.05$, ** denotes $P < 0.01$.

The implications for classroom science teaching and activities and future research are discussed.

MATERIALS AND METHODS

Structure of the sample and sampling

The sample, recognized as a simple random sample from the hypothetical statistical mass comprised primary and secondary school teachers in Slovenia. We collected 186 questionnaires in the year 2008 as part of the compulsory activities during practical work in schools by pre-service Biology teachers in the course, Didactics of Biology.

Teachers were assigned to one of two groups according to the type of school: compulsory 9-year primary school and secondary school. The first group consisted of teachers working at compulsory 9-year schools and the second one of teachers working at general secondary schools (gymnasium), technical and vocational schools. Some of the technical and vocational schools may have classes for technical gymnasium. (The structure of the Slovene school system is available online: http://www.mss.gov.si/en/areas_of_work/ education_in_slovenia/). In our sample, 88 (47.3%) teachers were from compulsory 9-year schools and 98 (52.7%) from high schools, for a total of 186.

It was a greater challenge to assign each teacher to a single group based on the subjects taught. Except in general high schools where teachers most often teach a single subject, the situation is completely different in 9-year compulsory schools and vocational schools. In the first three years of primary school all subjects are taught by one teacher; in middle school (grades 4 to 6) most of the subjects are taught by a class teacher, but some special subjects can be taught by others, and in lower secondary school the diversity is the greatest. Depending on previous schooling, teachers of, for example, Biology can teach diverse combinations of subjects, like Biology and Chemistry, Biology and Geography or even Biology and a foreign language. Because our sample size did not allow us to group teachers according to the subject taught, we formed two groups:

a) The first group (N = 49; 26.3%) comprise teachers who teach Biology regardless of any second or third subject;

b) The second group comprise teachers of all other subjects (N = 119; 64%) and primary school teachers (18; 9.7%) who did not have courses in Genetics, Biotechnology or related disciplines in their university studies.

In our study we did not ask about gender, even though it has been reported that there exist differences in attitudes toward biotechnology between men and women (Prokop et al. 2007). The reason is the predominance of female teachers in Slovene schools: In compulsory 9-year schools, 86.4% of the staff (data include full- and part-time instructional, professional support and management staff) are women, and in secondary schools 65.4% of the staff were women in the school year 2003/2004 (http://www.stat.si/letopis/2005/06_05/06-22-05.html). Among Biology teachers (where teaching about biotechnology most probably occurs) in secondary schools, about 90% of the teachers are female (Šorgo et al. 2007). We did not investigate differences according to years of teaching experience. Even if there are differences in knowledge and beliefs among different age-classes of teachers, these are unimportant for planned teacher training, because we cannot for practical reasons announce in-service training in biotechnology “for older (younger) teachers only”.

Structure of the questionnaire

To find out teachers’ knowledge about, level of acceptance of and attitudes towards GMOs, a questionnaire was assembled. The questionnaire was divided into four parts: (1) personal data, education, subject, type of school; (2) knowledge; (3) attitudes, and (4) acceptance of GMO and was completed anonymously.

Knowledge concerning genetics, biotechnology and GMOs was evaluated through a true-false questionnaire consisting of 30 statements. Teachers had to choose among three options: yes; do not know; no. The correct answer on 17 statements was ‘yes’ and on 13 statements ‘no’, a device which prevented guessing. The statements could be assigned to two general fields. The first set included statements from general genetics, with topics mostly covered in high-school genetics courses. The second set consisted of statements from classic and modern biotechnology and legislation. The questionnaire statements were ordered randomly to prevent automatism in answering. The reliability of the questionnaire, expressed as Cronbach’s alpha, was 0.912, which can be recognized as

Table 1. Teachers' knowledge about GMO. The highest results are in bold.

	Statement	Correct answer	Correct	Incorrect	Do not know/empty
25	All mutations are harmful.	No	**132 76.3%**	11 6.4%	30 17.3%
9	Products from GMO (genetically modified organisms) must be labelled as containing GM components.	Yes	**128 74.0%**	3 1.7%	42 24.3%
14	Before application of GM (genetically modified) plants, it is obligatory to perform a risk assessment about possible harmful influences of GM plants on the health of people, animals (other organisms) and the environment.	Yes	**128 74.0%**	3 1.7%	42 24.3%
22	The sex of the child depends on male sex cells.	Yes	**128 74.0%**	25 14.5%	20 11.6%
3	Deoxyribonucleic acid (DNA) occurs only in genetically modified organisms.	No	**121 69.9%**	3 1.7%	49 28.3%
10	A cat can fertilize a female rabbit; the resulting young rabbits have shorter ears.	No	**118 68.2%**	6 3.5%	49 28.3%
13	Deoxyribonucleic acid (DNA) is a source of information for the synthesis of proteins.	Yes	**112 64.7%**	3 1.7%	58 33.5%
29	Cloning of human embryos is already possible.	Yes	**112 64.7%**	21 12.1%	40 23.1%
20	Ribonucleic acid (RNA) is a genetically modified form of deoxyribonucleic acid (DNA).	No	**108 62.4%**	4 2.3%	61 35.3%
5	Genes are sequences (of nucleotides) on chromosomes.	Yes	**106 61.3%**	8 4.6%	59 34.1%
11	Mutations are the result of cloning.	No	**105 60.7%**	34 19.7%	34 19.7%
26	Bread rising is a biotechnological process.	Yes	**104 60.1%**	23 13.3%	46 26.6%
12	Mutations are always inherited.	No	**100 57.8%**	38 22.0%	35 20.2%
4	Bacteria genes from yogurt that can be consumed can be incorporated into cells in the human organism.	No	**84 48.6%**	10 5.8%	79 45.7%
28	Stem cells occur in adult humans.	Yes	**74 42.8%**	41 23.7%	58 33.5%
17	Therapeutic cloning from stem cells harvested from an adult produces several types of cells, used for treating diseases or harmful tissues of the same person.	Yes	73 42.2%	10 5.8%	**90 52.0%**
19	Recessive genes are never expressed.	No	70 40.5%	17 9.8%	**86 49.7%**
16	Therapeutic cloning from cells harvested from an adult, produces an embryo, the source of embryonic stem cells, which develop into several types of cells, used for treating diseases or harmful tissues of the same person.	Yes	69 39.9%	14 8.1%	**90 52.0%**

6	Genes are not normally transmitted from species to species in nature.	Yes	67 38.7%	**68** **39.3%**	38 22.0%
23	Biogas methane from biogas reactors is produced by bacteria.	Yes	66 38.2%	14 8.1%	**93** **53.8%**
18	Propagation of plants by cuttings is cloning.	Yes	59 34.1%	**81** **46.8%**	33 19.1%
1	Bacteria have the ability to mutually exchange genes.	Yes	57 32.9%	25 14.5%	**91** **52.6%**
30	The transfer of animal genes to plants is possible.	Yes	57 32.9%	36 20.8%	**80** **46.2%**
21	Slovenia has passed a law dealing with GMOs.	Yes	39 22.5%	34 19.7%	**100** **57.8%**
27	The cloning of genes and the cloning of organisms require the same methods of work.	No	37 21.4%	17 9.8%	**119** **68.8%**
24	In Slovenia only GM corn is produced and marked as MON 810.	No	35 20.2%	11 6.4%	**127** **73.4%**
8	Insulin for treating human diabetes is produced from GM (genetically modified) pig and cow pancreata.	No	30 17.3%	42 24.3%	**101** **58.4%**
7	GM crops are cultivated in Slovenia.	No	19 11.0%	**95** **54.9%**	59 34.1%
2	The vaccine against hepatitis B used to vaccinate all school children was produced with genetically modified yeast.	Yes	15 8.7%	23 13.3%	**135** **78.0%**
15	Reproductive cloning from cells harvested from an adult produces an embryo from which develops a child genetically identical to this adult.	No	5 2.9%	**117** **67.6%**	51 29.5%

*Unless stated; LOQ = Limit of quantification, lactic acid = 0.03%; mean value and standard deviation of three determinations are presented.

very good or could even mean that the list of statements could have been shorter. As a measure of knowledge, the sum of correct answers was used to calculate correlations and to compare means among different kind of teachers. In Table 1 frequencies and percentages of correct, incorrect, and do not know answers are reported.

In the third part the purpose was to measure attitudes and opinions toward GMOs. Attitudes toward GMOs were evaluated through a closed questionnaire, using a five-point Likert scale (5 Strongly agree, 4 Agree, 3 Neutral, 2 Disagree, 1 Strongly disagree). Twenty-eight statements were provided. We tried to recognize attitudes toward different applications, so we provided statements from various fields, such as health-medical applications, food application, farming, education, and society and research (science) applications. Additionally all statements regardless of field can be grouped into two subgroups: In the first group feelings like anxiety, gladness, anger and concerns are explored, and the second subgroup includes statements where we explored preparation for action. The first group can be recognized as passive with no action foreseen to change something and the second as active willingness to potentially or actually take an action pro or contra GMOs. In the questionnaire, we used a mixed approach, so in some cases disagreement with a statement represents a positive attitude in reality. For the purposes of statistical analysis, we numerically coded such statements in the opposite direction. Oposite coded statements are designated with an asterisk (*) in the tables. In this way it is possible to compare means and calculate sums for individual teachers. As a general measure of attitudes toward GMOs, we can use the means, and in cases when we are tracking a single teacher, the sum of points received on answers. So, a teacher who would in all cases strongly agree with the given statements and in that way express a positive attitude toward GMOs would get the maximum of 140 points, while in contrast, a teacher expressing the most negative attitudes would receive 28 points. The reliability of the questionnaire, expressed as Cronbach's alpha, is

Table 2. Acceptance level of different kinds of genetically modified organisms (GMO). The highest frequencies of answers are in bold.

	1*		2**		3***	
Genetically modified organisms	**N**	**%**	**N**	**%**	**N**	**%**
Microorganisms						
Microorganisms with the ability to synthesize medicinal substances (for example insulin)	**132**	**71.0**	34	18.3	20	10.8
Microorganisms that can degrade toxic or harmful substances previously biologically non-degradable	**121**	**65.1**	34	18.3	31	16.7
Microorganisms with the ability to synthesize applicable organic substances (for example various organic acids) to produce high value organic compounds	**101**	**54.3**	59	31.7	26	14.0
Microorganisms used for organic synthesis in the food industry (for example, bioethanol)	59	31.7	**87**	**46.8**	40	21.5
Genetically modified viruses designed for the transfer of genes between organisms	24	12.9	**92**	**49.5**	70	37.6
Plants						
Crop plants with increased tolerance to stress conditions (for example drought, salinity, etc.)	**107**	**57.5**	47	25.3	32	17.2
Plants used for producing biofuel	**103**	**55.4**	46	24.7	37	19.9
Plants with the ability to synthesize medicinal substances	**103**	**55.4**	50	26.9	33	17.7
Plants for human food resistant to pests and pathogens	66	35.5	46	24.7	**74**	39.8
Plants for animal food resistant to pests and pathogens	61	32.8	52	28.0	**73**	39.2
Plants for human food with improved quality characteristics of fruit (for example, prolonged cold storage, more intense coloration, etc.)	42	22.6	48	25.8	**96**	51.6
Ornamental garden plants with new properties (for example, blue carnations)	39	21.0	52	28.0	**95**	51.1
Ornamental house plants with new properties (for example, ornamental plants that glow in the dark)	37	19.9	36	19.4	**113**	60.8
Animals						
Animals, for example goats that produce milk containing medicinal substances (for example, coagulation blood factor)	58	31.2	47	25.3	**81**	**43.5**
Animals reared as donors for GM organ transplants (replacing or repairing defective organs or tissue)	57	30.6	53	28.5	**76**	**40.9**
Domesticated animals with new properties (for example, cats with no-shed or non-allergenic fur)	49	26.3	45	24.2	**92**	**49.5**
Animals for food consumption having meat with improved characteristics (for example, meat with low fat or with more intense colour)	34	18.3	53	28.5	**99**	**53.2**

*1 = acceptable; **2 = do not have an opinion, don't know; ***3 = not acceptable

0.867, which can be recognized as very good. Detailed analysis of the attitudes questionnaire is beyond the scope of this paper.

Acceptance of GMOs was evaluated with a closed questionnaire, where teachers were asked to circle an answer on a 17-item list of different existing or potentially existent GMOs (Table 2) and in such way express their opinion about them. We provided three answers: 1- acceptable; 2- don't know, do not have an opinion; 3- not acceptable. The level of acceptance was expressed as the number of different GM organisms that were acceptable to these teachers. Thus the maximum score was 17 for a teacher for whom all items were acceptable and the minimum zero, in the case of a teacher for whom all items are unacceptable. The questionnaire had a reliability level, expressed as Cronbach's alpha, of 0.905, which can be recognized as very good.

Data analysis

Analysis of the results followed three tracks and the statistical package SPSS® 12.0 was used for data analysis. Chi-square (χ^2) statistics were used to identify differences in frequencies of answers among different groups of teachers. In preliminary studies when we tried to identify differences among answers within a set of statements the Mann-Whitney and the Kruskall-Wallis non-parametric tests were performed because of their robustness. To compare differences in means among different groups of teachers, the F-test was performed, and to correlate their answers, the Pearson correlation coefficient was used. Symbols used in the figures are: * denotes $P < 0.05$, ** denotes $P < 0.01$.

RESULTS

Knowledge

As a measure of knowledge we used a sum of correct answers, where the highest possible score obtained from single teacher was 30. The mean result for the whole sample was close to 15 (N = 167; M = 14.8; SD = 6.2) and the median at 16. Nineteen teachers, four from 9-year schools and 15 from secondary schools left this part of the questionnaire blank, which could signal their limited knowledge of biotechnology and genetics issues and their reluctance to reveal this. Among teachers who answered this selection we found no statistically significant differences in knowledge among teachers from 9-year compulsory schools (M = 14.0; SD = 6.1) and high schools (M = 15.6; SD = 6.3) (F (1,166) = 2.491; p = 0.116), so we can recognize them as a single group. The highest scores were 27 in the first group and 26 in the second, a result which mean that some teachers possess an excellent level of knowledge.

The differences were, as expected, greater and statistically significant (F (2, 166) = 18,198; p = 0.000) among biology teachers (N = 47; M = 19; SD = 4.3) and teachers of other subjects (N = 120; M = 13.2; SD = 6.2). When correct statements from the whole teacher population were summarized (Table 1), we were able to recognize that only 13 statements out of 28 were correctly answered by 50% of teachers or more regardless of the subject, and a pattern that most correct answers were produced by statements from the classical genetics curriculum (DNA structure, replication, gene code for proteins, mutation, etc.), while the majority of teachers have poor knowledge about issues concerning modern biotechnology. The exception was knowledge about the need to label GMOs and about risk assessment for possible harmful influences (consequences, effects) of GM plants on the health of people, animals (and other organisms) and the environment - all of, which are statements more from the field of consumer rights and legislation than from biotechnology as a scientific discipline.

In analysing the answers to individual questions, we were surprised to recognize that 6 out of 173 (3.5%) teachers believe that 'A cat can fertilize a female rabbit; the resulting young rabbits have shorter ears', while only 68.2% could provide the correct answer. Moreover, only three-quarters of respondents know, that 'The sex of the child depends on male sex cells'.

Attitudes toward GMOs

In-depth analysis of the attitudes is beyond the scope of this work, so it will be presented only briefly. Summative attitudes toward GMOs are presented as means and standard deviations in Table 3. For the purpose of clarity, we have sorted them in to subscales. Attitudes toward GMOs used in calculating the correlations were calculated as the sum of scores on a five-point scale. We were able to calculate 181 sums, of which the mean was 79 (SD = 14.8) and the median 80. The maximum was 123 points and the minimum, 46 points. We did not find statistically significant differences (F (1,180) = 0.766; p = 0.383) in attitudes between Biology teachers (N = 49; M = 80.1; SD = 15.3) and teachers of other subjects (N = 132, M = 78.39, SD = 14.6) or between teachers (F (1, 180) = 0,671; p = 0.414) coming from compulsory 9-year school (N = 87; M = 79.9; SD = 13.9) and those from secondary schools (N = 94; M = 78.1; SD = 14.8).

From results presented in Table 3, it was possible to recognize that teachers, not surprisingly, scored more highly on agreement with statements connected to the importance of education about GMO. The most points were given to the statement that, besides the facts, teaching should also introduce values, morals and ethics to the students. The results are not as clear-cut for the univocal statements concerning research, where we recognize a pattern that they do not oppose research and trust researchers but have some concerns.

On the other hand, the greatest resistance is created by statements related to putting GMOs in the body. Besides resistance to putting anything containing GM inside the body, teachers don't even want to eat anything that was fed with GMO and behave in the same way. The same is true for medical applications. The rejection probably lies in a combination of "putting things containing GM inside the

Table 3. Means (M) and standard deviations (SD) of attitudes toward GMOs evaluated through a closed questionnaire, using a five-point Likert scale (5 Strongly agree, 4 Agree, 3 Neutral, 2 Disagree, 1 Strongly disagree). Statements marked with an asterix were coded in the opposite direction, because disagreement with such statements means a positive attitude towards such statement. Means calculated from uncoded data are presented in parentheses.

Statement	M	SD
Health and Medicine		
*I am afraid that bacterial resistance to antibiotics may increase because of GMOs.	2.08 (3.92)	1.07
I would worry about children's health if school meals were prepared from GMOs.	2.18	1.07
*I fear that the consequence of GMO usage will be an increased number of allergies.	2.20 (3.80)	1.01
I would be glad if we could breed animal - organ donors by gene manipulation.	2.89	1.19
If I had an illness caused by genetic malfunction, I would choose treatment by gene therapy.	3.03	1.11
*I would rather die than have an organ from a GM animal transplanted into my body.	3.67 (2.33)	1.10
Food		
*I would be angry if foodstuffs produced from GMOs weren't marked.	1.69 (4.31)	0.83
*I would be worried if the effects of GMO consumption could show up after a long time period.	1.84 (4.16)	0.93
*On no account would I buy foodstuffs containing GMOs.	2.92 (3.08)	1.19
*If I received a gift of chocolate containing fats from GM soya, I would throw it away.	3.01 (2.99)	1.33
I would prefer foodstuffs from GMOs if they were healthier than foodstuffs obtained conventionally.	3,22	1.27
Farming		
*Beef from animals fed with fodder that was cultivated with pesticides is more acceptable to me than beef from animals fed with genetically modified fodder.	3.45 (2.55)	1.03
*Apples genetically modified by genes from other sorts of apples are not acceptable to me.	3.10 (2.90)	1.23
I would buy a GM ornamental house plant out of curiosity.	2.85	1.20
Genetically modified plants are more acceptable than genetically modified animals.	2.53	1.23
It would be good for farmers to cultivate GMOs because they would use less spray for pests and pathogens.	2.36	1.17
*I would worry that GMOs could cross into the environment.	2.32 (3.68)	1.12
*I would worry about nature if I knew that farmers cultivated GMOs.	2.30 (3.70)	1.09

I would plant genetically modified plants in my garden.	2.17	1.15
Education		
Teaching about GMOs should, besides the facts, also introduce values and a moral and ethical component.	4.21	0.87
Pupils are not capable of creating their own system of values about GMOs and need to be guided by teachers.	3.98	0.97
Education about GMOs should be organized for all school teachers, regardless of the subject they teach.	3.92	1.06
GMOs should be a topic in subjects such as Biology or Domestic Science and not in other school subjects.	2.21	1.16
Society and research		
GMO research should be additionally stimulated.	3.49	1.28
All society should benefit from GMOs, not only their producers.	3.33	1.27
*GMO research should be stopped until it is clear that it is entirely safe.	3.02 (2.98)	1.38
*Production of GMOs is against the laws of nature and should be forbidden.	2.93 (3.07)	1.22
*Researchers working on GMOs conceal from us data about their harmful effects.	2.34 (3.66)	1.03

body", and the majority would rather die than allow hypothetical transplantation of organs from GM animals into their bodies.

Acceptance of GMOs

In-depth analysis of the acceptance of different kinds of GMOs (Table 2) is beyond the scope of this work, so it is presented only briefly in the discussion section. Acceptance of the GMOs was calculated as the number of organisms that a teacher can accept. The mean value was 6.4 (SD = 4.6) and the median, 6. We did not find statistically significant differences ($F(1, 185) = 0.181$; $p = 0.671$) between teachers coming from compulsory 9-year schools (N = 88; M = 6.3; SD = 4.8) and secondary schools (N = 98; M = 6.6; SD = 4.5). A statistically significant difference ($F(1, 185) = 5.386$; $p = 0.021$) does exist between teachers of biology (N = 49; M = 7.7; SD = 4.1) and teachers of other subjects (N = 137; M = 5.9; SD = 4.7).

The correlation among knowledge, attitude and acceptance level was calculated. It was a surprise to recognize that there was no correlation between knowledge and attitudes, only a weak correlation between knowledge and acceptance, and a solid correlation between attitudes and acceptance (Figure 1). To confirm our finding that knowledge is not the most important factor behind the acceptance of GMOs, we performed correlation analysis among those teachers who achieved the highest scores on the knowledge test. We included in our analysis teachers who received 20 points or more on the 30-point test (Table 1). In the group of achievers, correlations between knowledge and attitudes and knowledge and acceptance are even slightly weaker than in the general population. In the contrast, the correlation between attitudes and acceptance of GMOs is even higher (Figure 2).

DISCUSSION

It is obvious (Table 1) that almost the entire Slovene teacher population has some basic knowledge of genetics. Knowledge of classic genetic issues can most probably be attributed to high school education, where courses in Biology are obligatory for the whole student population in schools that allow students to enter university degrees in teacher education. Although the knowledge of some of the teachers can be appraised as very good or even excellent in general, we cannot be satisfied with these levels. Judging from some answers (hybridization of cats and rabbits, inheritance of sex), we can infer serious flaws in the quality of such education in some cases. Biology teachers are, not surprisingly, more knowledgeable in genetics than their colleagues teaching other subjects. Knowledge about the application of modern biotechnology, about the benefits and potential risks of these technologies for human society and the environment is worse in both groups. In the case of all the non-biology teachers, we cannot attribute this knowledge to formal education but to other informal sources, such as the media, internet, and environmental groups - which is most probably the explanation for their lower scores. In general, Biology teachers may be better educated in genetics and technology, but for the sociological, humanistic and ethical aspects of such issues they rely on informal sources.

In most cases the attitudes toward GMOs according to the calculated means are not extreme. Teachers support education about GMOs that involves values, and a moral and ethical component and is not limited to Science subjects. They support research that is transparent and trust the researchers. However, they reject GMOs especially when their use involves applications in food production, putting such organisms or products into their body or even anything fed with GMO; this pattern has been recognized elsewhere in Europe (Ronteltap et al. 2007; Christoph et al. 2008). The same is true for medical applications, and the majority would rather die than allow hypothetical transplantation of organs from GM animals.

Several studies have examined public opinion and attitudes towards biotechnology and related issues (Chen and Raffan, 1999; Hoban, 2004; Sadler and Zeidler, 2005a; Sadler and Zeidler, 2005b; Plahuta et al. 2007; Prokop et al. 2007; Ronteltap et al. 2007; Allum et al. 2008; Christoph et al. 2008), and it was expected that, in line with other studies, teachers with a higher level of knowledge of biotechnology would also have more positive attitudes toward GMOs. However, the correlation between knowledge and attitudes in our teachers with higher levels of knowledge was, to the contrary, even slightly lower than in their less informed colleagues. A similar trend was already observed when informative material activated negative attitudes toward GM food (Grunert et al. 2003; Scholderer and Frewer, 2003; Ronteltap et al. 2007), while biology students with more knowledge of biotechnology had similar rather than more positive attitudes toward biotechnology, than students not studying biology (Prokop et al. 2007). Almost similar findings emerged from a study by Johnson and Pigliucci (2004) concerning pseudoscientific claims, where they found that knowledge of scientific facts and an understanding of how science works are not associated with the degree of belief in pseudoscience. Our findings are also in line with those of Jallinoja and Aro (2000) and Ekborg (2008) that greater knowledge does not simply direct attitudes in a more positive direction, but that more informed individuals separate into two groups with more extreme opinions on the issue, and even those who can recognize such GMOs as useful did not necessarily believe them to be safe (Cavanagh et al. 2005). Furthermore, supporters and opponents most often have better knowledge than those who remain indifferent (Scholder and Frewer, 2003; Ronteltap et al. 2007). Both supporters and opponents seem to be engaged in the topic, while the group of indifferent (don't know?) respondents contains many fewer respondents with good levels of knowledge, which may be an indication of low involvement (Christoph et al. 2008). It also seems that the correlation between general knowledge and a range of specific application of science as genetic modifications is weaker than the correlation between general knowledge and general attitudes toward science. So, understanding of social and psychological mechanisms that generate differences in association that exist between knowledge and attitudes about science and GMOs must be an important future challenge of research (Allum et al. 2008).

When discussing acceptance, we were able to recognize two patterns. The first one is that GM microorganisms and plants are generally more acceptable than GM animals. Our results confirm that acceptance of one type of GMO does not mean that some other GMO will also be acceptable (Stewart and McLean, 2005). The second pattern is that GMOs not used for food consumption are generally more acceptable if they or their parts cannot be used directly for consumption and produce something recognized as useful for purposes such as medicine, bio-fuel, or organic substances, and have the capacity to clean something, or to improve resistance to stress conditions. It was interesting to find a drop in the level of acceptance in pairs, for example, where plants tolerant to stress are acceptable to more than half of the teachers, while on the other hand, if plants are manipulated to be tolerant to pests in food production, they are recognized as acceptable by only one third of respondents. It was a surprise that, among plants, the lowest scores were given to ornamental plants; a finding which can mean that acceptance of an organism is in correlation with its perceived usefulness and benefits. Genetically manipulated animals generally fall on the lower side of acceptability, especially if they have been manipulated for food consumption. The lowest scores were given to genetically modified viruses. We can speculate that the answers somehow correlate with knowledge of and attitudes towards viruses in general, because viruses as the cause of disease do not have a good reputation among people and are not recognized as useful. The pattern that consumers barely accept GMOs produced for food consumption is discussed in Ronteltap et al. (2007).

In the uncertainty group (do not know; do not have an opinion), there were no organisms crossing the fifty percent border. Closest to this number were the manipulated viruses (N = 92, 49.5%) and microorganisms manipulated for production of substances for the food industry (N = 87, 46.8%). Teachers are most confident (uncertainty below 20%) when they have to declare as acceptable microorganisms that can be used for degradation of toxic or harmful substances and microorganisms that can synthesize medicinal substances, while they find ornamental house plants unacceptable.

Correlation between knowledge and acceptance is weak but stronger between attitudes and acceptance (Figure 1). When we calculated correlations for teachers who had received 20 or more points in the test of knowledge, we found that the correlation between knowledge and acceptance was even weaker, but that the correlation between attitudes and acceptance was higher. As a result, we can conclude that decisions about and acceptance of genetically modified products are rarely based on scientific facts and formal reasoning but more often on informal reasoning, a finding that holds true for other socio-scientific issues, too (Sadler, 2004; Sadler and Zeidler, 2005a; Sadler and Zeidler, 2005b).

After the study and from the point of teacher educators, we know that Slovenian Biology teachers possess solid knowledge about classical genetics (DNA structure, replication, gene code for proteins, mutation, etc.) and know less about current applications of modern biotechnology (genetic engineering, modifying and manipulating the DNA of an organism, recombinant DNA technology, etc.). The level of knowledge in non-biology teachers is in both aspects much lower. From the standpoint of teacher educators, this could mean that we should prepare two separate in-service courses: one for the Biology teachers, regardless of the school, and the second course for all other teachers, regardless of their school of origin. In the course for Biology teachers, the major part of the course should be based on Biotechnology issues. The course for other teachers should have an additional refresher course in genetics, while the second part should be information about biotechnology.

If we know how to teach teachers about scientific part of socio-scientific issues, in our case GMOs, then the major challenge is how to reconstruct attitudes based on unscientific reasoning. The greatest obstacle in changing attitudes is that attitudes are deeply rooted and will not easily be changed by information (Grunert et al. 2003). Consumer acceptance of innovations has been studied in various disciplines and from many theoretical perspectives, and several attitudinal models of innovation acceptance have been applied (Grunert et al. 2003; Ronteltap et al. 2007; Christoph et al. 2008), none of which were designed for use in teacher trainings. Our study and other similar ones have demonstrated that attitudes are not correlated and will not change with additional knowledge, so challenging attitudes by simply informing teachers is probably a waste of time. Perhaps we should test a strategy based on the knowledge that, on the other hand, acceptance significantly correlates with attitudes, and only slightly with knowledge. If the correlation between acceptance and attitudes is bidirectional, then changes in the level of acceptance could probably enhance a change in attitudes, with no guarantee that acceptance of one group of GM organisms would automatically be transferred to other groups. There are several suggestions in the literature for igniting such changes, mostly prepared for GM foods. Prokop et al. (2007) proposed that attitudes change where consumers have the chance to get first hand experience with GMOs, so exposing teachers to such experience with GM foods in a workshop should work. In other cases, where direct exposure to such organisms or techniques is impossible, we should use other strategies. Lewis and Leach (2006) proposed carefully designed and contextualized education about GMO in the direction of critical thinking, with analysis of arguments and defence of individual viewpoints, with no need for huge amounts of knowledge. The purpose of such education should not be to force teachers to have more positive attitudes, but to help them understand the risks, benefits, and disadvantages of genetic modification, and not simply to rely on their emotions. They have to learn how to evaluate student attitudes towards and acceptance of GM, how to adapt their lessons to current understanding and to choose appropriate activities (Chen and Raffan, 1999). To achieve this goal, we should choose themes that provide in-depth specific knowledge about actual cases, instead of touching light on a number of different areas of GMOs (Ekborg, 2008). By learning which questions to ask and acquiring the skill to interpret the information, opinion might be formed on specific arguments rather than on fear, emotion or blind trust. It is also necessary for teachers to know more about the nature of science and scientific methods.

CONCLUDING REMARKS

Although our study shows that teachers' levels of knowledge are not a determinant of acceptance, we should begin by briefly reviewing classical (high school) genetics, followed by more detailed explanation of topics from biotechnology and legislation. It is clear that carefully designed education about GMO should take the direction of critical thinking, with analysis of arguments and adoption of an individual critical position. We can help teachers to understand the risks, benefits and disadvantages of genetic modification. We propose to let them choose themes for in-depth study. We must prepare them to work with pupils and students, to modify their lessons according to current understanding and to select appropriate activities congruent with their knowledge, attitudes and level of acceptance. How to educate current and future teachers, how to prepare themes for a variety of issues discussed in society, how to form one's own opinion on topics as complicated as GMOs, how to introduce socio-scientific issues into the educational system - these are questions for further work in teacher education.

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